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Catheter Ablation From Right Atrium of Anteroseptal Accessory Pathways Using Radiofrequency Current

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Catheter ablation with radiofrequency current has recently been introduced as a therapeutic regimen for symptomatic patients with the Wolff-Parkinson-White syndrome or atrioventricular (AV) tachycardia mediated by a retrogradely conducting (concealed) accessory AV pathway. These pathways may be located, although infrequently, in the anteroseptal region of the heart in close proximity to the AV node-His bundle conduction system. Any attempt to interrupt an anteroseptal accessory pathway therefore is subject to the potential complication of inadvertent impairment of normal AV conduction. This study was conducted to establish whether abolition of anteroseptal accessory pathways by radiofrequency current aimed at the atrial as opposed to the ventricular insertion of the pathway can be achieved with preservation of AV node-His bundle conduction.

Twelve patients (mean age 37 ± 13 years; 10 with Wolff-Parkinson-White syndrome, 2 with a concealed accessory pathway) were studied. In the majority of patients, radiofrequency current (500 kHz; mean energy 577 ± 207 J) was applied through a steerable catheter with a long tip electrode placed in the anterior septal space at the atrial aspect of the tricuspid anulus, with the intention to destroy the atrial insertion of the accessory pathway. All pathways were successfully ablated. The AV node or His bundle conduction was not impaired in any patient. Right bundle branch block was induced in two patients (17%). There were no complications related to the procedure.

It is concluded that catheter ablation from the right atrium using radiofrequency current provides effective and safe interruption of anteroseptal accessory pathways with good preservation of the normal conduction system.

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Patients with the Wolff-Parkinson-White syndrome may present with severely symptomatic supraventricular tachyarrhythmias. The anatomic substrate of the syndrome is an accessory atrioventricular (AV) connection, which may function as part of the reentrant circuit in reciprocating AV tachycardia or serve as a conduit for rapid conduction of atrial fibrillation to the ventricles. The ensuing ventricular fibrillation poses a life-threatening hazard in the latter subgroup of patients with the Wolff-Parkinson-White syndrome.

Among accessory AV pathways, those located in the anteroseptal space are the least common. Their incidence, primarily on the right side of the heart, has been reported to be 10% (1). Anteroseptal accessory pathways may course from the atrium to the ventricle in close anatomic proximity to the specialized conduction system (2) and a surgical or electrical attempt to ablate these pathways is subject to the potential complication of inadvertent interruption of AV node-His bundle conduction.

In patients in whom antiarrhythmic medication is either ineffective or not tolerated or in young patients who do not wish to have life-long pharmacologic therapy, surgical division of the accessory AV pathway guided by electrophysiologic mapping has evolved into a curative therapeutic approach with high efficacy and low mortality and morbidity rates (3–9). Because of the complex morphology of that cardiac region, only the endocardial surgical approach, requiring a median sternotomy, cardiopulmonary bypass and right atriotomy, has been successfully used to interrupt anteroseptal accessory pathways with preservation of AV node conduction (2,3,10). However, the inherent costs and low but definite risk and morbidity of surgery make an alternative therapeutic approach desirable to cure patients with symptomatic tachyarrhythmias mediated by an accessory pathway.

Catheter ablation using radiofrequency current is increasingly being investigated for its efficacy and safety in the setting of accessory pathways at various sites along the AV anuli (11–17). The preliminary success rates reported from these centers vary between 67% and 99% and the acute complication rate appears to be low. Initial results have recently been presented (18) for patients with an anteroseptal accessory pathway. The present study is based on our experience (19–21) with radiofrequency current catheter ablation of accessory pathways and describes the technique in patients with a right-sided anteroseptal pathway. Special attention is given to the effects on AV node and His bundle conduction of current delivery to the accessory pathway.

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Methods

Study patients. Among 159 patients who underwent attempts at catheter ablation of accessory pathways using radiofrequency current at our institution between May 1987 and July 1991, 12 had an anteroseptal accessory pathway. There were 2 women and 10 men, with a mean age of 37 ± 13 years. All were free of organic heart disease. Ten patients had the Wolff-Parkinson-White syndrome, with manifest pre-excitation on the surface electrocardiogram (ECG) and the delta wave pattern suggesting an anteroseptal location of the accessory pathway (8,22) and two had a concealed accessory pathway capable of retrograde conduction (from ventricle to atrium) only. In two of the former patients, the accessory pathway conducted intermittently in an anterograde but permanently in a retrograde direction (intermittent Wolff-Parkinson-White syndrome). One of them (Patient 1) suffered from incessant reentrant AV tachycardia. Two patients were found to have multiple accessory pathways; a single additional pathway was observed at a right posterior location in Patient 5 and two additional pathways were found at right mid-septal and left lateral locations, respectively, in Patient 7. All three associated pathways had "overt" (that is, consistent bidirectional) conduction properties. Patient 3 was found to have an associated nodoventricular Mahaim fiber.

Symptoms, including frequent and disabling palpitation in all patients, with associated dizziness and nausea in two, had been present for 2 to 23 years. Patient 5 had survived an episode of cardiac arrest precipitated by ventricular fibrillation; this patient had previously undergone surgery for Wolff-Parkinson-White syndrome at another institution, as well as catheter ablation for a left posteroseptal pathway. Reentrant atrioventricular (AV) tachycardia was the underlying type of arrhythmia in 11 patients, associated with atrial fibrillation in 3, including the patient with a history of cardiac arrest. Atrial fibrillation was exclusively present in Patient 2. Six patients had never undergone pharmacologic arrhythmia therapy; a mean of 3 ± 2 antiarrhythmic agents had been ineffective or were not tolerated in the other six patients.

All patients were informed about the experimental nature of the catheter ablation procedure and gave their written consent. The protocol was approved by the Ethics Committee at the University of Hamburg.

Electrophysiologic procedure. For stimulation purposes, standard production quadripolar 6F catheters (USCI) were advanced through the femoral veins to the high right atrium and right ventricular apex. A hexapolar 6F catheter (USCI, 2-mm interelectrode distance) introduced from the right femoral vein was placed across the tricuspid valve to record His bundle potentials. A 6F catheter with three groups of four circumferential electrodes arranged in an orthogonal configuration ("Jackman" catheter; Mansfield/Webster Catheters, Mansfield Scientific, Inc.) was positioned from the left subclavian vein into the coronary sinus for coronary sinus mapping. For mapping of the anteroseptal endocardial aspect of the tricuspid anulus and eventual application of radiofrequency energy, two different catheters were employed in the course of this study. In the first two patients, the mapping/ablation catheter was a standard 6F quadripolar model (USCI); in the remaining patients a steerable 7F quadripolar catheter with a 5-mm interelectrode distance and a large tip electrode of 4 mm length (Mansfield/Webster or Dr. Osypka GmbH, Grenzach-Wyhlen) was used. Either catheter was introduced from the right internal jugular vein and positioned against the tricuspid anulus in search of sites of earliest retrograde atrial activation and earliest anterograde ventricular activation and for accessory pathway activation potentials. Mapping was performed during orthodromic reciprocating tachycardia (or during right ventricular pacing when retrograde conduction across the AV node was excluded) and during sinus rhythm or atrial pacing.

An anteroseptal location of the accessory pathway was assumed if a pathway potential as well as a (large) His bundle potential were simultaneously recorded from the catheter probing the bundle of His area. With this catheter left in place, the presumed accessory pathway location was then verified by careful mapping of the anteroseptal and anterior region of the tricuspid anulus using the ablation catheter. The optimal site chosen for radiofrequency current application was one from which large atrial and ventricular potentials were recorded (reflecting a catheter position directly at the tricuspid anulus) in conjunction with an accessory pathway potential but no or just a tiny His bundle potential (Fig. 1 and 2). Catheter positioning was performed in the 30° right and left anterior oblique fluoroscopic views (Fig. 3). The estimated minimal distances between the tip electrodes of the ablation and His bundle catheters in both views were recorded.

Radiofrequency current catheter ablation technique. Radiofrequency current was applied between the tip electrode of the mapping/ablation catheter and a patch electrode below the patient's left scapula. Current was delivered in the eight patients with consistent manifest Wolff-Parkinson-White syndrome during sinus rhythm, and in patients with intermittent Wolff-Parkinson-White syndrome or a concealed accessory pathway during orthodromic AV tachycardia (termination of the tachycardia due to loss of retrograde atrial activation would indicate conduction block in the accessory pathway).

An ablation attempt was considered successful if at the end of the procedure both anterograde and retrograde accessory pathway conduction had disappeared or if retrograde conduction through the concealed pathway was no longer present. After successful ablation of an accessory pathway, one additional "safety" application was given after 1 min to the same site to minimize the possibility of a late recurrence of accessory pathway conduction.

Electrophysiologic evaluation was performed 30 to 60 min after successful accessory pathway ablation. It consisted of right atrial and ventricular stimulation using the extrastimulus technique as well as incremental pacing to

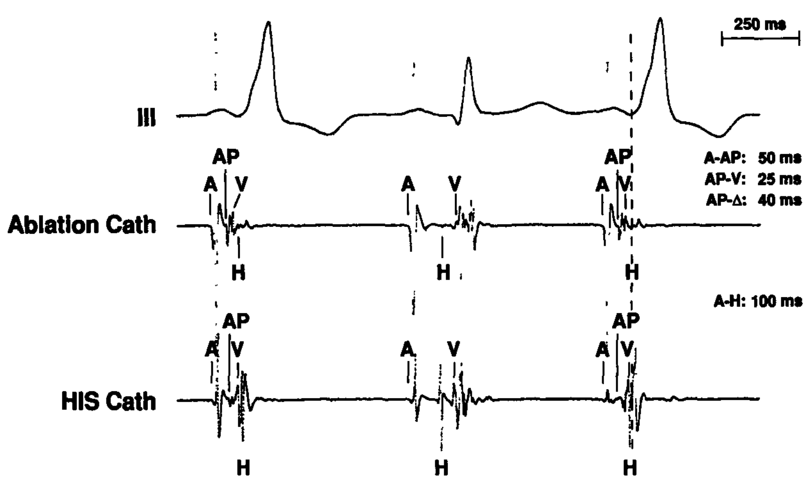

Figure 1. Patient 8. Surface electrocardiographic lead III and two intracardiac electrograms recorded before ablation and during sinus rhythm in a patient with an overt accessory pathway. The first and third beats are pre-excited; the middle beat shows normal ventricular activation due to transient accessory pathway block. The His bundle catheter (HIS Cath) **(bottom tracing)** records a distinct accessory pathway potential (AP) and a large His bundle potential (H) during the first and third beats, indicating an anteroseptal location of the accessory pathway. The ablation catheter (Ablation Cath) **(middle tracing)**, located at the atrial insertion of the accessory pathway, also records an accessory pathway potential but only a tiny His bundle potential. Note the large amplitude of the atrial potential (A) in this tracing. During the second beat, no accessory pathway potentials are recorded from either catheter, but the difference in amplitude of the His bundle potentials can be appreciated. The **broken vertical line** in the third beat indicates the onset of the delta wave (Δ). V = ventricular potential.

exclude the presence of another accessory pathway and to determine the postablation conduction properties of the AV node-His bundle system.

During the procedure, patients were sedated if necessary with diazepam (5 to 15 mg) or were anesthetized with fentanyl (0.1 to 0.5 mg). After catheter positioning, a bolus injection of 100 U/kg body weight of heparin was given intravenously, followed by a second injection of 5,000 U after 4 h.

Devices. Programmed electrical stimulation with stimuli of 0.5-ms duration at twice diastolic threshold was performed with the ERA-S-HIS stimulator (Biotronik GmbH). A custom-built generator supplying unmodulated 300-kHz alternating current at constant preset voltages for variable periods of time was used for accessory pathway ablation in the first two patients. A 500-kHz generator (HAT 200, Dr. Osypka GmbH) was used in all other patients. With the latter generator, relevant data of radiofrequency current delivery (power, duration, cumulative energy) are stored on a personal computer system that does not provide for calculation of voltage, current or impedance. Current was delivered for 20 to 30 s except in Patient 5, who received two 60-s pulses because of unstable catheter-wall contact.

Follow-up. After the ablation session, the first four patients were monitored in the intensive care ward for 48 h. Because supraventricular or ventricular arrhythmias were never observed, the remaining patients were transferred to the regular patient ward. A two-dimensional echocardiogram was performed each day, surface ECGs were recorded twice daily and the serum creatine kinase value was determined every 6 h for the 1st 2 days. All patients were discharged within 2 to 5 days on a daily dose of 300 mg of aspirin as prophylaxis against thrombus formation (23).

Patients were then seen in the outpatient clinic after 1 and 3 months and every 6 months thereafter. At each visit, the patient's clinical course was assessed, a physical examination performed and a surface ECG and two-dimensional echocardiogram were recorded.

Statistical analysis. Data are presented as mean values ± 1 SD where appropriate. In cases of an asymmetric distribution of measured variables, the median value is given

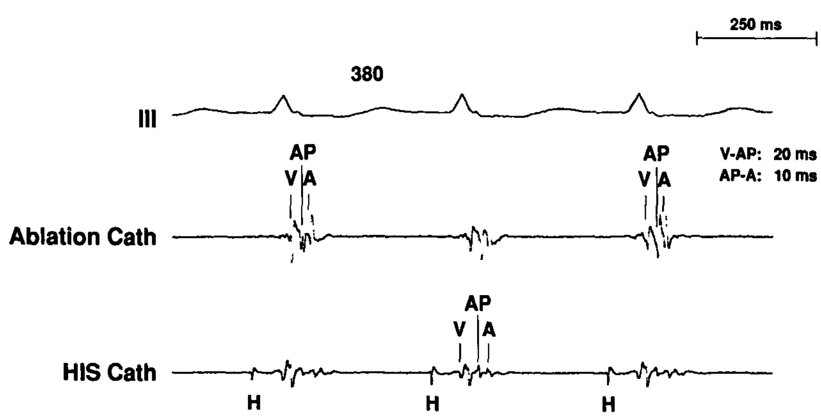

Figure 2. Patient 5. Surface electrocardiographic lead III and two intracardiac electrograms recorded before ablation and during orthodromic atrioventricular tachycardia in a patient with a concealed accessory pathway. In analogy to Figure 1, the His bundle catheter records distinct His bundle (H) and accessory pathway (AP) potentials and the ablation catheter records an accessory pathway but no His bundle potential. Tachycardia cycle length is 380 ms. Abbreviations as in Figure 1.

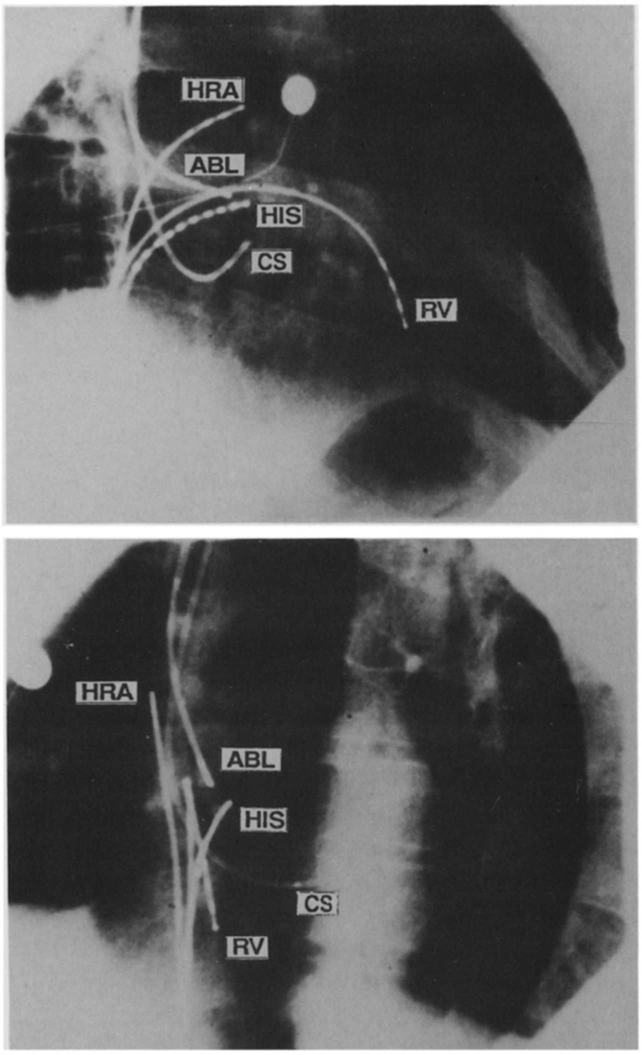

Figure 3. Radiographs illustrating the relative positions of the His bundle catheter (HIS) and the ablation catheter (ABL) before ablation. The long tip electrode of the ablation catheter is located at the atrial insertion of the anteroseptal accessory pathway. Also shown are stimulation catheters at the high right atrium (HRA) and right ventricular apex (RV) and a coronary sinus catheter (CS). **Top panel,** 30° right anterior oblique view; **bottom panel,** 30° left anterior oblique view.

instead of the mean. Comparisons between continuous variables were analyzed with the Mann-Whitney U test.

Results

General ablation data (Table 1). Fourteen ablation sessions were performed in the 12 patients and resulted in permanent abolition of accessory pathway conduction in all 12. This result was achieved in a single ablation procedure, except in the 1st two patients, who were exclusively treated with the standard tip electrode catheter and who required a repeat session the next day. The mean radiofrequency power delivered in the four sessions using a standard tip catheter was significantly less than that applied through the large tip electrode catheter used in the remaining 10 patients (7.9 ± 1.1 vs. 25.3 ± 4.7 W; $p < 0.01$). The duration of current delivery averaged 20.4 ± 5.9 s for all sessions, resulting in a mean energy per application of 127 ± 54 J for sessions using the standard tip electrode catheter and 577 ± 207 J ($p < 0.01$) for sessions using the large tip electrode catheter. The median number of radiofrequency pulses applied per session was 7 (range 2 to 42). Sessions lasted a mean of 4 ± 1.1 h and radiation exposure for catheter positioning averaged 44.1 ± 25.4 min.

Catheter positions and data related to accessory pathway potentials (Table 2). The relative positions of His bundle and ablation catheters for a successful attempt at ablation is reflected in the tip to tip distances for the 30° right and left anterior oblique fluoroscopic views. They averaged 5.2 and 5.4 mm, respectively, representing an anterior location of the ablation catheter in relation to the His bundle catheter (Fig. 3). Accessory pathway potentials were recorded in all but one patient. For the ablation catheter positioned at a site of eventually successful pathway interruption, Table 2 summarizes the conduction intervals related to an accessory pathway potential as well as the amplitude ratio of atrial and ventricular potentials. During anterograde conduction, the accessory pathway potential preceded the local ventricular potential and the onset of the delta wave by 24 ± 6 and 37 ± 10 ms, respectively. The atrial/ventricular potential ratio ranged between 1.5 and 20 (mean 6.6).

Effect on atrioventricular (AV) conduction (Table 3). Transient mechanical block of accessory pathway conduction by manipulation of the ablation catheter was repeatedly encountered in five patients, with the maximal duration of accessory pathway block ranging between 18 and 115 min. Permanent heart block or impairment of AV node or His bundle conduction was not induced in any patient. The only effect on the specialized conduction system observed after radiofrequency current application to the accessory pathway was right bundle branch block in two patients (17%). There were no acute or late complications related to the ablation procedure.

Associated accessory pathways. The associated accessory pathways present in two patients were also successfully interrupted by radiofrequency current application. In Patient 5, a delta wave in the presence of atrial fibrillation recurred and a repeat procedure was performed 3 months after the session that had resulted in abolition of the anteroseptal pathway (Fig. 4). In Patient 7, one associated pathway was ablated in the same session during which the anteroseptal pathway was interrupted, while the third pathway, a right mid-septal pathway, required a repeat ablation procedure the next day because accessory pathway conduction recurred after 3 h. The associated nodoventricular Mahaim fiber present in Patient 3 was ablated with radiofrequency current in the same session that resulted in abolition of the anteroseptal AV pathway.

Follow-up. During a median follow-up period of 5.7 months (range 0.5 to 27.8), all but one patient (Patient 2) were without antiarrhythmic medication and free of arrhyth-

Table 1. Patient Characteristics and Ablation Session Data

			RFC Applications						
						Energy (J)			
Pt No.	Age (yr)/ Gender	WPW	No.	Mean Power (W)	Mean Duration (s)	Cumulative	Mean	Session Dur (h)	Rad Exp (min)
1	29/M	Overt, intmt	5	7.5	16.8	647	129	3.00	—
			15	9.2	20.0	2,717	194	3.50	10.4
2	61/M	Overt	10	6.6	18.8	1,242	124	6.50	37.0
			3	8.4	7.6	186	62	3.25	17.1
3*	22/F	Overt	3	24.5	22.0	1,679	560	4.00	36.4
4	39/M	Overt	42	30.5	17.4	23,246	553	4.50	92.5
5†	28/M	Overt	5	30.0	36.0	5,400	1,080	3.50	83.9
6	50/M	Concealed	4	26.5	20.0	2,123	531	2.33	34.5
7‡	24/M	Overt	7	19.4	19.3	2,611	373	5.25	59.5
8	29/F	Overt	2	18.0	20.0	718	359	3.50	15.0
9	41/M	Overt	15	28.7	22.9	9,899	660	3.00	41.2
10	45/M	Overt	9	20.1	22.2	4,059	451	4.50	39.4
11	52/M	Overt, intmt	14	29.7	22.8	9,791	699	3.67	68.0
12	28/M	Concealed	7	25.5	20.0	3,572	510	5.33	37.8

*Associated Mahaim fiber; †associated right posterior overt accessory pathway (AP); ‡associated left lateral and right mid-septal overt accessory pathways. Dur = duration; F = female; intmt = intermittent; M = male; Pt = patient; Rad Exp = radiation exposure time; RFC = radiofrequency current; WPW = Wolff-Parkinson-White conduction characteristics of an accessory pathway.

mia-related symptoms. Echocardiographic and ECG findings were normal except in Patient 2, in whom a delta wave was recorded at the 1-year follow-up visit. He has remained asymptomatic on treatment with oral flecainide (200 mg/day) and is scheduled for another attempt at catheter ablation.

Discussion

This study demonstrates that radiofrequency current can be applied to the anteroseptal region for successful interruption of an accessory atrioventricular (AV) pathway without compromising AV node-His bundle conduction. It supplies further evidence that catheter ablation may be safely directed at an accessory pathway at any location along the AV anuli (20,21).

Methodology. Recent methodologic achievements have paved the way for catheter ablation to be attempted in patients with an anteroseptally located accessory pathway. The delivery of radiofrequency energy as opposed to direct-current shocks produces a rather circumscript area of tissue necrosis by means of a thermal effect and thus avoids the complications related to shock-inflicted barotrauma (24–26). Because of the discrete lesions produced by radiofrequency current, the precise localization of the pathway site is a prerequisite for successful accessory pathway ablation. This has been facilitated by the advent of steerable catheters with

Table 2. Conduction Intervals Related to an Accessory Pathway Potential and Catheter Distances

Pt No.	A-AP (ms)	AP-V (ms)	AP-Δ (ms)	V-AP (ms)	AP-A (ms)	A/V	d (RAO) (mm)	d (LAO) (mm)
1*	—	—	—	30	20	5.0	5.0	7.0
2†	—	—	—	—	—	8.0	4.0	8.0
3	30	30	40	—	—	7.5	4.0	5.0
4	40	20	30	—	—	7.0	4.0	6.0
5	40	20	20	—	—	5.0	6.0	10.0
6	—	—	—	20	10	3.0	3.0	6.0
7	60	30	30	—	—	14.0	4.0	2.0
8	50	25	40	—	—	20.0	10.0	5.0
9	30	30	50	—	—	1.5	3.0	5.0
10	35	15	35	30	40	2.0	5.0	2.0
11*	20	25	50	—	—	1.7	4.0	7.0
12	—	—	—	30	30	4.5	10.0	2.0
Mean	38	24	37	28	25	6.6	5.2	5.4
±1 SD	13	6	10	5	13	5.5	2.4	2.5

*Intermittent Wolff-Parkinson-White syndrome; †no AP potential recorded. A = atrial deflection; A/V = atrial/ventricular deflection amplitude ratio; d = distance; LAO = 30° left anterior oblique view; RAO = 30° right anterior oblique view; V = ventricle; Δ = onset of delta wave; other abbreviations as in Table 1.

Table 3. Basic Electrophysiologic Data

	Preablation								Postablation						
	CI 1:1 via AP		CI 1:1 via AVN		AH				CI 1:1 via AVN		AH		HV		
Pt No.	Ant	Ret	Ant	Ret	SR	BCL 510	TCL	Mech AP Block	Ant	Ret	SR	BCL 510	SR	BCL 510	RBBB
1	—	280	—	—	90	100	310	No	310	VA diss	90	90	50	50	No
2	310	270	—	—	50	—	340	Yes	320	VA diss	90	90	30	30	No
3	370	400	—	—	—	—	460	Yes	300	VA diss	50	70	40	40	No
4	330	300	—	—	60	70	360	No	310	VA diss	60	70	50	50	Yes
5	300	340	—	—	—	—	320	No	250	320	40	30	40	40	No
6	—	260	340	—	70	90	380	No	340	VA diss	60	80	50	50	Yes
7	290	350	—	—	40	—	—	Yes	250	290	40	50	60	60	No
8	380	280	—	—	100	100	—	Yes	390	VA diss	90	90	40	40	No
9	350	260	250	—	50	50	300	Yes	240	260	60	60	40	40	No
10	640	250	250	—	60	60	280	No	260	VA diss	60	60	30	30	No
11	—	450	370	—	60	60	—	No	370	330	70	70	30	30	No
12	—	370	400	—	90	90	400	No	380	330	90	90	40	40	No
Mean	371	318	322	—	67	78	350		310	306	67	71	42	42	
±1 SD	113	64	69		20	20	57		53	30	19	19	9	9	

All values are in milliseconds. Ant = anterograde; AVN = atrioventricular node; BCL = basic drive cycle length; CI = coupling interval; mech = mechanically induced; RBBB = right bundle branch block; Ret = retrograde; SR = sinus rhythm; TCL = tachycardia cycle length; VA diss = ventriculoatrial dissociation; other abbreviations as in Table 1.

a large tip electrode (4 mm in length). These catheters have an additional advantage in that increased electrical power (in the 25-W range) may be applied to the tissue for ≥20 s without current breakdown due to the increased impedance caused by sudden boiling at the electrode-tissue interface (27,28). Moreover, the identification of the "weak" part along the atrium-accessory pathway-ventricle axis as achieved by direct recordings of accessory pathway potentials has led to a differential approach to pathways located at either the right or left side of the heart (21,29,30).

Anatomic considerations. The AV node and His bundle are located in the posteroseptal area, with the compact AV node enclosed in the posterior aspect of the atrial septum just posterior to the membranous ventricular septum. The penetrating His bundle passes through the central fibrous body into the muscular ventricular septum where it bifurcates into the left and right bundle branches. The right bundle branch spreads subendocardially along the right ventricular muscular septum. Anteroseptal accessory pathways course from atrium to ventricle skirting the right fibrous trigone or the central fibrous body (2,31).

Surgical ablation. Surgical ablation of accessory pathways has become the standard treatment for symptomatic patients with an accessory pathway (3–9). The different surgical approaches have proved to be equally effective and safe in experienced centers. Because of the complex anatomy of the anteroseptal region, accessory pathways within this region can be ablated only with the endocardial approach (10). Although complete heart block has occurred after surgical intervention, primarily for posteroseptal accessory pathways (3,9), it has not been reported for anteroseptal pathways (2,10). This is explained by the fact that the His bundle is protected by a fibrous "shield" consisting of the central fibrous body and the membranous septum. Preservation of normal AV conduction is therefore essential for any nonsurgical approach to abolition of anteroseptal accessory pathways.

Catheter ablation of anteroseptal pathways. Radiofrequency current applied at the atrial aspect of the tricuspid anulus to a site where an accessory pathway potential can be recorded allows the interruption of accessory pathway conduction without altering AV node conduction. This demonstrates that at the energies used in this study, the lesion is localized enough to avoid functional damage to the AV node-His bundle system despite its proximity to the accessory pathway. Positioning of the ablation catheter at the atrial aspect of the tricuspid anulus was readily achieved through the right internal jugular vein, particularly with the steerable large tip electrode catheter. The location of the catheter at the site of the accessory pathway was verified in most cases by the recording of an accessory pathway potential in conjunction with a distinct ventricular and atrial potential. Previous studies (30) have demonstrated that the site of accessory pathway block in such a location is at the atrial insertion of the accessory pathway and it appears logical that this site, rather than the site of ventricular insertion, is the one to which radiofrequency current is directed.

In all cases, accessory pathway ablation was successful when radiofrequency current was applied to an area anterior to the catheter recording His bundle activity. The observation that transient loss of pre-excitation is frequently induced mechanically (by catheter manipulation) in this group of patients indicates a close subendocardial course of anteroseptal pathways that facilitates catheter ablation. How-

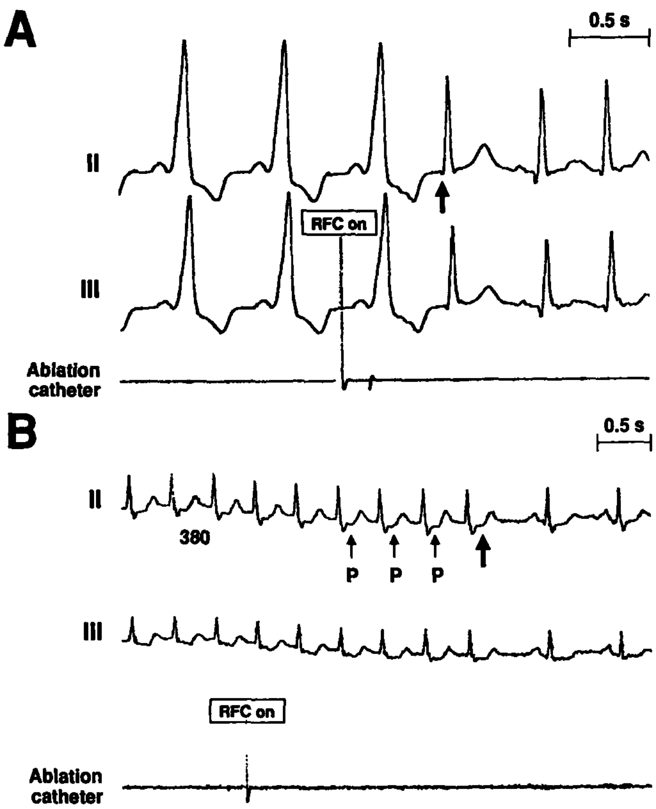

Figure 4. Application of radiofrequency current in two patients with an anteroseptal accessory pathway. Shown are tracings from electrocardiographic leads II and III and the ablation catheter lead. **A,** Patient 8 (overt pathway). After radiofrequency current application (RFC on) during sinus rhythm, there is almost immediate loss of accessory pathway conduction, reflected by disappearance (**arrow**) of the prominent delta waves present in the first three beats. **B,** Patient 5 (concealed pathway). Radiofrequency current is delivered (RFC on) during atrioventricular tachycardia of 380 ms cycle length. Tachycardia persists for another 1.8 s before sinus rhythm is reinstated. Tachycardia termination is caused by loss of accessory pathway conduction, reflected by disappearance (**large arrow**) of retrograde P waves (**small arrows** indicate the last three).

ever, transient accessory pathway block may sometimes persist for up to 2 h and may thus prolong the procedure.

Although the accessory pathway and the normal conduction pathway are frequently located very close to each other (2), this study shows that they can be separated electrophysiologically by a precise mapping technique. The recording of an accessory pathway potential turned out to be an important prerequisite for pathway ablation. For eventually successful applications of radiofrequency current, an accessory pathway potential was found to occur for overt pathways before the local ventricular potential and the onset of the delta wave at mean intervals of 24 and 37 ms, respectively.

Side effects. Right bundle branch block was induced in 2 (17%) of the 12 patients. This possibly confirms the observation that in some patients the catheter location at a right atrial site is unstable as compared with the rather stable ventricular catheter position recommended in patients with a left-sided accessory pathway (21). Catheter displacement toward the right ventricular septum during radiofrequency current application may have accounted for the induction of right bundle branch block in both patients. Future improvements in the design of electrode catheters may allow for more catheter stability at the atrial aspect of the tricuspid anulus so that this complication can be avoided. In a recently published preliminary study (18) of eight patients with an anteroseptally located accessory pathway in whom radiofrequency current catheter ablation of the pathway was attempted from the right ventricle, a much higher incidence (five patients, 63%) of induced right bundle branch block was reported.

Limitations of the study. The number of patients included in the present study is small and follow-up is limited to maximally 28 months, with a median of approximately 6 months. At present, these factors restrict the confident evaluation of the incidence of acutely induced right bundle branch block and long-term effects on the specific conduction system. The low recurrence rate of accessory pathway conduction after initially successful pathway ablation is concordant with findings in a much larger series of patients (20,21). It is of note that accessory pathway conduction recurred only in the patient in whom no accessory pathway potential could be recorded through the ablation catheter before the application of radiofrequency current. In retrospect, this finding suggests that ablation was attempted from a catheter location that was suboptimal despite the initially successful pathway interruption from this location. The 1-year recurrence of accessory pathway conduction in this patient is nevertheless exceptional and cannot be fully explained.

Conclusions. Catheter ablation of anteroseptal accessory pathways with radiofrequency current aiming at the atrial insertion of the accessory pathway is highly effective and appears to be safe. The AV node-His bundle conduction can be preserved, but there is a 17% chance that infra-His conduction will be impaired by the intervention. Long-term data obtained from larger series of patients are needed for further evidence that this approach may be the treatment of first choice in symptomatic patients with an anteroseptally located accessory pathway.

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References

1. Reddy GV, Schamroth L. The localization of bypass tracts in the Wolff-Parkinson-White syndrome from the surface electrocardiogram. Am Heart J 1987;113:984–93.
2. Sealy WC. Kent bundles in the anterior septal space. Ann Thorac Surg 1983;36:180–6.
3. Cox JL, Gallagher JJ, Cain ME. Experience with 118 consecutive patients undergoing operation for the Wolff-Parkinson-White syndrome. J Thorac Cardiovasc Surg 1985;90:490–501.

4. Bredikis J, Bukauskas F, Zebrauskas R, et al. Cryosurgical ablation of right parietal and septal accessory atrioventricular connections without the use of extracorporeal circulation: a new surgical technique. J Thorac Cardiovasc Surg 1985;90:206–11.
5. Guiraudon GM, Klein GJ, Sharma AD, Milstein S, McLellan DG. Closed-heart technique for Wolff-Parkinson-White syndrome: further experience and potential limitations. Ann Thorac Surg 1986;42:651–7.
6. Mahomed Y, King RD, Zipes DP, et al. Surgical division of Wolff-Parkinson-White pathways utilizing the closed-heart technique: a 2-year experience in 47 patients. Ann Thorac Surg 1988;45:495–504.
7. Pagé PL, Pelletier LC, Kaltenbrunner W, Vitali E, Roy D, Nadeau R. Surgical treatment of the Wolff-Parkinson-White syndrome: endocardial versus epicardial approach. J Thorac Cardiovasc Surg 1990;100:83–7.
8. Menasché P, Leclercq JF, Cauchemez B, et al. Surgery for the Wolff-Parkinson-White syndrome in 73 consecutive patients: what have we learnt from intraoperative mapping? Eur J Cardiothorac Surg 1989;3:387–91.
9. Frank G, Baumgart D, Lowes D, et al. Chirurgische Behandlung des Wolff-Parkinson-White-Syndroms: Erfahrungen mit 87 operierten Patienten. Z Kardiol 1990;79:37–45.
10. Guiraudon GM, Klein GJ, Sharma AD, Yee R, Pineda EA, McLellan DG. Surgical approach to anterior septal accessory pathways in 20 patients with the Wolff-Parkinson-White syndrome. Eur J Cardiothorac Surg 1988;2:201–6.
11. Jackman WM, Wang X, Friday KJ, et al. Catheter ablation of accessory atrioventricular pathways (Wolff-Parkinson-White syndrome) by radiofrequency current. N Engl J Med 1991;324:1605–11.
12. Calkins H, Sousa J, Rosenheck S, et al. Diagnosis and cure of the Wolff-Parkinson-White syndrome or paroxysmal supraventricular tachycardias during a single electrophysiologic test. N Engl J Med 1991;324:1612–8.
13. Borggrefe M, Hief C, Karbenn U, et al. Catheter ablation of accessory pathways using radiofrequency energy: improvement of results with the use of a large tip electrode catheter (abstr). J Am Coll Cardiol 1991;17:109A.
14. Miles WM, Klein LS, Gering LE, et al. Efficacy and safety of catheter ablation using radiofrequency energy in patients with accessory pathways (abstr). J Am Coll Cardiol 1991;17:232A.
15. Kay GN, Epstein AE, Crossley GH, Daily SM, Plumb VJ. Radiofrequency ablation of accessory pathways (abstr). J Am Coll Cardiol 1991;17:366A.
16. Tracy C, Swartz J, Fletcher R, Weston L, Soloman A, Karasik P. Atrial endocardial radiofrequency ablation of accessory pathways (abstr). J Am Coll Cardiol 1991;17:368A.
17. Fitzgerald DM, Matista J, Arnold L, Haisty WK Jr. Radiofrequency current ablation of accessory pathways: initial experience and limitations (abstr). J Am Coll Cardiol 1991;17:368A.
18. Twidale N, Wang X, Moulton K, et al. Catheter placement for radiofrequency ablation of anteroseptal accessory pathways (abstr). J Am Coll Cardiol 1991;17:231A.
19. Kuck KH, Kunze KP, Schlüter M, Geiger M, Jackman WM. Ablation of a left-sided free-wall accessory pathway by percutaneous catheter application of radio-frequency current in a patient with the Wolff-Parkinson-White syndrome. PACE 1989;12:1681–90.
20. Kuck KH, Schlüter M, Geiger M, Siebels J, Duckeck W. Radiofrequency current catheter ablation of accessory atrioventricular pathways. Lancet 1991;337:1557–61.
21. Schlüter M, Geiger M, Siebels J, Duckeck W, Kuck KH. Catheter ablation using radiofrequency current to cure symptomatic patients with tachyarrhythmias related to an accessory atrioventricular pathway. Circulation 1991;84:1644–61.
22. Gallagher JJ, Pritchett EL, Sealy WC, Kasell J, Wallace AG. The preexcitation syndromes. Prog Cardiovasc Dis 1978;20:285–327.
23. Kunze KP, Schlüter M, Costard A, Nienaber CA, Kuck KH. Right atrial thrombus formation after transvenous catheter ablation of the atrioventricular node. J Am Coll Cardiol 1985;6:1428–30.
24. Jackman WM, Kuck KH, Naccarelli GV, Carmen L, Pitha J. Radiofrequency current directed across the mitral anulus with a bipolar epicardial-endocardial catheter electrode configuration in dogs. Circulation 1988;78:1288–98.
25. Huang SKS. Radiofrequency catheter ablation of cardiac arrhythmias: appraisal of an evolving therapeutic modality. Am Heart J 1989;118:1317–23.
26. Borggrefe M, Hindricks G, Haverkamp W, Breithardt G. Catheter ablation using radiofrequency energy. Clin Cardiol 1990;13:127–31.
27. Langberg JJ, Lee MA, Chin MC, Rosenqvist M. Radiofrequency catheter ablation: the effect of electrode size on lesion volume in vivo. PACE 1990;13:1242–8.
28. Haines DE, Verow AF. Observations on electrode-tissue interface temperature and effect on electrical impedance during radiofrequency ablation of ventricular myocardium. Circulation 1990;82:1034–8.
29. Jackman WM, Friday KJ, Scherlag BJ, et al. Direct endocardial recording from an accessory atrioventricular pathway: localization of the site of block, effect of antiarrhythmic drugs, and attempt at nonsurgical ablation. Circulation 1983;68:906–16.
30. Kuck KH, Friday KJ, Kunze KP, Schlüter M, Lazzara R, Jackman WM. Sites of conduction block in accessory atrioventricular pathways: basis for concealed accessory pathways. Circulation 1990;82:407–17.
31. Becker AE, Anderson RH. Morphology of the human atrioventricular junctional area. In: Wellens HJJ, Lie KL, Janse MJ, eds. The Conduction System of the Heart. Philadelphia: Lea & Febiger, 1976:263–86.